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EFFECT OF SELECTED PRE-TREATMENTS ON THE FUNCTIONAL AND PASTING PROPERTIES OF PIGEON PEA FLOUR

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ABSTRACT: *The effect of three different processing conditions (fermentation, steaming and roasting) on the functional and pasting properties of an under-utilised legume pigeon pea were investigated. This study aimed to optimise these processing conditions for the processing of pigeon peas. Response Surface Methodology (RSM) based on a 3-level full factorial of the Random sample design was selected to optimise the effect of fermentation, steaming and roasting on the quality parameters of pigeon peas. The quality parameters of the pre-treated beans: functional and pasting properties were determined to see the effects of the pre-treatment using standard laboratory procedures. For functional properties, values obtained were: bulk density (0.64 - 0.81)g/ml, water absorption capacity (123.64-174.64)%, oil absorption capacity (78.8-106.13)% , swelling capacity (11.60-27.96)%, foaming capacity 5.57-15.15 and foam stability (0.84 and 6.25)%. Values obtained for pasting properties have their regression coefficient (R2) as peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature as 0.69, 0.05, 0.51, 0.37, 0.34, 0.07 and 0.54 respectively while the adjusted R2 values for same parameters were 0.39, -0.09, 0.04, -0.25, -0.32, -0.87 and 0.07 respectively. Furthermore, the Coefficient of Variation (CV) derived for peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature was 8.86, 19.24, 35.03, 4.99, 27.34, 16.57 and 4.29 respectively. The response surface plots depict the effects of steaming temperature and steaming time on the pasting properties of fermented pigeon pea flours. The optimum conditions for the variables investigated with fermented, steamed, and roasted pigeon peas with suitable quality characteristics were fermentation temperature of 270C for 4 days, steaming at 100oC for 20 minutes, and roasting at 1400C for 8 minutes. The pasting properties are also reflective of the functional properties so also the response surface plots. This information will be necessary for the utilisation of pigeon peas with improved physical conditions for exploitation on a large scale.*

KEYWORDS: Pigeon pea, Pre-treatment, Fermentation, Roasting, Steaming, Functional and Pasting

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INTRODUCTION

Pigeon pea (*Cajanus cajan (L.)*) ranks fifth in importance among edible legumes in the world (Rachie and Wurster, 2007). Although India remains the major producer of pigeon peas, the interest in pigeon peas in other parts of the world, including Nigeria, is a result of their nutritional, medicinal, economic and agronomic usefulness. The pigeon pea is a locally available, affordable and under-utilised grain legume of the tropics and sub-tropics. Pigeon pea varieties have protein content in the range of 23 – 26 % (Akporhonor *et al.,* 2006). The protein content is comparable with those of other legumes like cowpea and groundnut, which have been used in complementing maise. It is rich in mineral content and fibre content. Pigeon pea grows well in Nigeria, but the hard-to-cook phenomenon and the presence of antinutrients have limited its utilisation (Fasoyiro *et al.,* 2010).

Similarly, the characteristic problem of the hard-to-cook phenomenon also hinders the extensive use of pigeon peas as food. The dried seeds are hard, and by the traditional processing methods, it takes 24 hours to prepare a meal of pigeon peas (Amarteifio *et al.,* 2002). Various methods have been used to improve the food value of pigeon peas by improving their processing, storage, preservation and utilisation. Such methods include germination (Onimawo and Asuqo, 2004), fermentation, toasting (Onimawo and Akubor, 2012), boiling and irradiation (Onimawo and Akubor, 2012). The processing methods employed in the preparation of pigeon peas may affect the physicochemical properties of the seeds hence, their potential food application. Moderate heat treatment has been reported to improve the digestibility of plant proteins without developing toxic derivatives and to inactivate several enzymes such as proteases, lipases, lipoxygenases, amylases and other oxidative and hydrolytic enzymes. Roasting is the most significant step in the processing of different seeds, which causes important physical, chemical, structural and sensorial changes.

The roasting process could promote more flavour, and desired colour, increase the palatability and improve the efficiency of subsequent treatment (Onimawo and Akubor, 2012). One of the main desired outcomes of the roasting process is the increase in antioxidant activity that occurs mainly due to the formation of Maillard reaction products. Boiling helped to destroy protease inhibitors and cyanogen in pigeon peas. Toasting and boiling have been reported to enhance the taste and flavour of foods. Fermentation gives the food longer, keeping quality; it helps develop flavour and decreases antinutritional factors in foods (Onimawo and Akubor, 2012). Cooking is the oldest method of grain processing. It improves the nutritive value of the protein in legumes and cereals. It makes the grain edible by making them tender and aids in flavour development. It generally inactivates heat-sensitive anti-nutritive factors such as trypsin, chymotrypsin inhibitors and volatile compounds. Cooking also improves palatability (Sheel-Sharma *et al.,* 2011).

Pigeon pea has been identified as an under-utilised food crop among many legumes despite its nutritional quality, especially in protein when compared to cowpea, groundnut, and soybean. Pigeon pea is reportedly rich in many nutrients but with some anti-nutritive factors. Subjecting the pigeon pea to these selected pre-treatment methods of fermentation, steaming, and roasting will improve the nutritive value and adversely reduce the anti-nutritional factors such as oxalate, saponins, tannin, and trypsin inhibitor. However, fermentation will reduce heat-stable anti-nutritional factors such as phytate and increase the digestibility of plant protein. The steaming process will eliminate labile anti-nutritional factors such as trypsin inhibitors and reduce its cooking time. Roasting will also improve the taste and edibility of the product and

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gives it a unique flavour which can increase its sensory appeal. Roasting also serve as a method of reducing anti-nutritional factors. The aim of this research is to determine the effects of selected pre-treatment methods on the properties of pigeon peas (*Cajanus cajan (L.)*) and the qualities of its products.

MATERIALS AND METHODS

The brown pigeon pea (*Cajanus cajan (L.)*) used for this research was obtained from the Oja-Oba Central market at Ilorin Kwara state and was identified at Botany Department, University of Ibadan, Oyo State. The equipment used, such as oven, bowls, sieve, attrition mill, trays, mixer, knives, and spoons, were obtained from the Department of Food Science, Ladoke Akintola University of Technology, Ogbomoso and Food Processing Laboratory of the Department of Food Technology, Federal Polytechnic, Offa, Kwara State, Nigeria.

Experimental Design

The experiment was designed using Response Surface Methodology; Design expert software (version 13.0) to study the effects of the selected pretreatments process on the quality of Pigeon pea and its products. The selected pre-treatment methods are fermentation, steaming and roasting, while the factors considered were time and temperature for the three pre-treatments. In order to determine the effects of time and temperature as factors of the pretreatments, a 3-level full factorial design was adopted. The design parameters and level of the different factors were carefully selected for fermentation temperatures of 27-30 ^oC for a time interval of 2-5 days according to Akindahunsi (2004), steaming temperature of 95-100 ^oC for 10-30 mins and roasting at temperatures of 140-180 ^oC for 7-10 minutes according to Fasoyiro *et al.* (2010a).

Production of fermented pigeon pea seed into flours

Pigeon pea seeds were fermented using the modified method of Adebowale and Maliki (2011). Raw pigeon pea seeds were sorted by hand-picking the dirt, stones and other extraneous materials, and one kilogram (1 kg) was weighed. It was washed thoroughly with clean water and thereafter soaked in water (1:3 W/V) at a formulated temperature and time produced by the experimental runs for fermentation to take place, as shown in Table 3.1. The soaked water was changed on a daily basis. At the end of the soaking period, the soaked water was discarded, and the pigeon pea was rinsed. The fermented seeds were dehulled using mortar and pestle, the seed coat was separated from the seeds, and the dehulled seeds were dried in a hot air oven at 60^0C for 8 hours. The dried fermented samples were ground into flour using a laboratory blender (Kenwood Blender model BL335). The fine powdered fermented pigeon pea flour was sieved using a mesh sieve size of 60 microns and was stored at room temperature (27±2 ^oC) in an airtight high-density polythene bag for further analysis.

Production of Steamed pigeon pea into Flour

Pigeon pea was steamed using the modified method of Fasoyiro *et al.* (2010b). Pigeon pea was sorted, after which one kilogram (1 kg) was weighed and thoroughly washed with clean water. The pigeon pea seeds were placed on a perforated stainless steel sieve and steamed over boiling water at formulation temperatures (95 ^oC, 97.5 ^oC and 100 ^oC) and time (10, 20 and 30 minutes) produced by the experimental runs (Table 3.2). The sample was rapidly cooled using cold

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water. The steamed seeds were dehulled using mortar and pestle, the seed coat was removed, and the dehulled seeds were oven dried at a temperature of 60 ^oC until constant moisture content was achieved. It was milled and sieved using a mesh sieve size of 60 microns, and the flour was stored in an air-tight polythene bag and stored under ambient temperature for further use.

Production of roasted pigeon pea into flour

Pigeon pea was roasted using the modified method of Fasoyiro *et al.* (2010b). The pigeon pea seeds were sorted to remove dirt, stones, leaf stalks and other extraneous materials, and 1 kg was weighed. The seeds were moistened with 500 ml of water. The moistened seeds were allowed to equilibrate for 15 min. The equilibrated pigeon pea seeds were then roasted using an electric fryer at formulation temperatures (140, 1600 and 180 ^oC) and time (7, 8.5 and 10 minutes) produced by the experimental runs (Table 3.3). The seeds were continuously stirred. The dehulled seeds were allowed to cool and dehulled using mortar and pestle, and the seed coat was winnowed from the seeds. The dehulled roasted seeds were milled into flour using an attrition milling machine and sieved to approximately a mesh size of 60 microns. The roasted pigeon pea flour was packaged and stored in an airtight container for further use.

Production of raw pigeon pea into flour (Control Sample)

The method of Echendu *et al.* (2004) with slight modifications was used for the preparation of raw pigeon pea flour. The pigeon pea seeds were sorted to remove dirt, stones, and other extraneous materials and winnowed. One kilogram of pigeon pea seeds was weighed out and soaked in cold water (30±2 ^oC) for 38 hours for easy removal of coats. The soaked pigeon pea seed was dehulled manually by rubbing the seeds in between the palm, the dehulled seeds were oven dried at 60 ^oC for 8 hours and milled using an attrition milling machine. The flour obtained was screened through an 80 mesh sieve micron, Flour obtained served as the control sample and was stored in an air-tight high-density polyethene bag at room temperature (27±2 ^oC).

Functional properties of the determination

Bulk density

The method described by Oladele and Aina (2007) was used for the determination of the bulk density. The flour sample was weighed (20g) into a 50 ml graduated measuring cylinder. The cylinder was tapped gently against the palm of the hand until a constant volume was obtained. Bulk density was calculated as;

$$\text{Bulk density} = \frac{Weight\ of\ sample}{Volume\ of\ sample\ after\ tapping}$$

Water absorption capacity

The water absorption capacity of the samples was determined by the method of Omowaye-Taiwo *et al.* (2015). Ten (10) ml of distilled water was added to 1.0 g of each flour sample; the suspension was stirred using a magnetic stirrer for 3 mins. The suspension was transferred into centrifuge tubes and centrifuged at 3,500 rpm for 30 mins. The supernatant obtained was measured using a 10 ml measuring cylinder. The density of the water will assume to be 1 g per ml. The water absorbed by the sample was calculated as the difference between the initial water

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used and the volume of the supernatant obtained after centrifuge. The result was expressed as a percentage of water absorbed by the blends on a %g/g basis.

$$\% \text{ WAC} = \frac{\textit{Weight of water absorbed x Density of water}}{\textit{Weight of the samples}} \times 100$$

Oil absorption capacity

The oil absorption capacity of the samples was determined by the method of Omowaye-Taiwo *et al.* (2015). The 10ml of oil of known specific gravity was added to 1g of sample in a beaker. The suspension will be stirred using a magnetic stirrer for 3 minutes. The suspension obtained was thereafter centrifuged at 3500 rpm for 30 minutes, and the supernatant was measured into a 10 ml graduated cylinder. The density of oil is to be 0.931 g/ml. The oil absorbed by the flour was calculated as the difference between the oil's initial volume and the supernatant's volume.

$$\%\text{OAC} = \frac{\textit{Weight of oil absorbedxDensity of oil}}{\textit{Weight of the samples}} \times 100$$

Swelling index

The swelling index of the samples was determined by the method of Awolu *et al.* (2017). Ten (10g) of the flour sample was weighed and poured into a 100-measuring cylinder, and the initial volume was taken. 60ml of water was then added and allowed to stand for 4h after stirring, and then the level of swelling was observed.

Swelling index $\text{S.I} = \frac{\textit{Volume after soaking - Volume before soaking}}{\textit{Weight of samples}} \times 100$

Foaming capacity and stability

Foaming capacity and stability were determined according to the method reported by Coffman and Garcia (2007). The flour sample was mixed thoroughly in a measured quantity of distilled water with a magnetic stirrer for about 5 min and transferred to a graduated measuring cylinder. The volume of the foam measured was used to calculate the foaming capacity, as shown.

$$\text{F.C}(\%) = \frac{Vol.after\ homogenization - vol.before\ homogenization}{Vol.before\ homogenization} \times 100$$

The foam volume that remained after a 10 min interval for 1 h was used to calculate the foaming stability as shown below

$$\text{F.S}(\%) = \frac{the\ volume\ of\ foam\ after\ a\ particular\ time}{initial\ volume\ of\ foam} \times 100$$

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Determination of Pasting Properties

Pasting characteristics was determined with a Rapid Visco-Analyser (RVA super 3, Newport Scientific pty. Ltd, Australia). A 3-g sample of flour (at 14% moisture level) was dissolved in 25 ml of water in a sample canister. The sample was thoroughly mixed and fit into the RVA as recommended (Ikegwu *et al.,* 2009). The slurry was heated from 50 to 95°C with a holding time of 2 min followed by cooling to 50 °C with another 2 min holding time. The 12-min profile was used, and the rate of heating and cooling was done at a constant rate of 11.25 °C/minute. Corresponding values for peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature from the pasting profile were read from a computer connected to the RVA.

Statistical Analysis

The data collected were subjected to statistical analysis using Statistical Package for Social Science (SPSS) version 21.0. Analysis of variance (ANOVA) was used to determine the differences at a 5% level of significance. In cases where differences occurred, the means were separated using Turkey's test according to Rattanathaanalerk *et al.* (2005).

RESULTS AND DISCUSSION

Effect of fermentation as pre-treatment on functional properties of pigeon pea

Functional properties are inherent physicochemical properties that can influence the behaviour of food systems during processing and storage (Akubor, 2017). They are the physicochemical properties that frequently influence how food systems function, particularly during preparation and storage (Akinjayeju *et al.*, 2020). As seen in Table 4.1, the bulk density value ranged from 0.64 to 0.81g/ml. The lowest pack bulk density values were obtained with a pigeon flour sample that underwent 5 days at a fermentation temperature of 30^{o}C. The bulk density of the sample fermented at a temperature of 27.50^{o}C, 30^{o}C and 25^{o}C for 5 days was observed to have no significant difference ($p<0.05$) among them, as seen in Table 1. The water absorption capacity of the flour sample ranged from 123.64 to 174.64%, with a significant difference ($p>0.05$) among all the samples. The oil absorption capacity of the fermented pigeon pea flour ranged from 78.8 to 106.13 %. All of the fermented flour samples exhibited a significant difference ($p>0.05$). The least oil absorption capacity was observed in pigeon peas fermented at a temperature of 25^{o}C for 3.5 days. Furthermore, the swelling capacity value ranged from 11.60 to 27.96%. The swelling capacity recorded the highest value in pigeon pea that was subjected to a fermentation process: fermentation temperature of 27.50^{o}C for 3.5 days. Meanwhile, pigeon pea samples fermented at 25^{o}C for two (2) days showed the least swelling capacity value. The foaming capacity was found to vary between 5.57 to 15.15, with significant ($p<0.05$) differences observed among all the samples as fermentation temperature and days changed. A closer look at Table 1 revealed that no significant ($p<0.05$) difference was seen between two samples that were fermented at the same temperature of 25 ^{o}C for 3 and 5 days. The value of foam stability of the fermented pigeon pea flour ranged between 0.84 and 6.25 %. A significant ($p<0.05$) difference was observed among the entire flour sample, irrespective of the processing condition. As shown in Figure 4.1, the foaming capacity grew as the fermentation temperature

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increased, but the swelling capacity decreased as fermentation progressed further (duration period increased). A slight increase was observed in the foam stability of the flour sample, but as the fermentation temperature increased further, a decrease in the value was observed.

Effect of the steaming process as pre-treatment on functional properties of pigeon pea

Table 2 shows the bulk density, water absorption capacity, oil absorption capacity, swelling capacity, foaming capacity and foaming stability of the steamed samples at various temperatures and times. They were observed to be in the range 0.59-0.67 g/ml, 127.13-154.51 %, 39.22-75.08 %, 10.19-36.09 %, 17.40-32.40 %, 1.14 - 4.35 %, respectively. The highest swelling capacity (36.09%) was observed in samples steamed at 95 ^oC for 20 minutes, while the samples with the highest oil absorption capacity (75.08%) were samples steamed at 100 ^oC for 30 minutes. The bulk density was observed to increase with an increase in steaming temperature, while it remained unchanged with an increase in the steaming time. All treatments in the present study involved a heating step, which may have led to the denaturation of proteins. It has been suggested that denaturation exposes hydrophilic and hydrophobic parts of proteins, thus affecting the water and oil absorption capacity (Aguilera *et al.*, 2009). The water absorption capacity was observed to increase with an increase in steaming temperature and also slightly increase with respect to an increase in steaming time. This is similar to the observation of Ma *et al*. (2011) and Benitez *et al.* (2013) on treated samples. This effect might be due to physical, structural differences of the boiled flours allowing greater porosity and fluid entrapment and/or greater water-binding properties of subunits or amino acid residues exposed as a result of denaturation (Aguilera *et al.*, 2009).

Oil absorption capacity has been attributed to the physical entrapment of oil within the protein and non-covalent bonds, such as hydrophobic, electrostatic and hydrogen bonds, which are the forces involved in lipid-protein interaction (Du *et al.*, 2014). A similar observation was observed on heat-treated samples by Ferawati *et al.* (2019) and Marisela *et al.* (2007). The decrease in the swelling capacity of the treated samples may be due to the pre-gelatinization of starch granules after legume grains were subjected to steaming. This may contribute to an increase in starch crystallinity and the strengthening of intermolecular bonds. This is due to the action of heat-moisture treatment, which further restricts the swelling of the starch granules (Singh *et al.,* 2011). Afolabi *et al.* (2018) reported a reduction in the swelling power for hydrothermally modified Bambara groundnut starches.

Foaming capacity was observed to increase with an increase in steaming temperature, whereas foaming stability, on the other hand, was observed to decrease with an increase in steaming temperature and later increase at temperatures close to 100 ^oC while the foaming stability remained unchanged with respect to the steaming time induced. Foaming capacity and foam expansion are related to the proteins' ability to diffuse rapidly to the interface, reorient, and form a viscous film without excessive aggregation or coagulation. In contrast, foaming stability is influenced by the intermolecular cohesiveness and viscosity of the film as well as a certain degree of elasticity permitting localised contact deformation (Ma *et al.*, 2011).

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Table 1: Effect of fermentation as pre-treatment on functional properties of pigeon pea

Temp. (°C)	Fermentation Days	Bulk Density (g/ml)	WAC (%)	OAC (%)	Swelling Capacity (%)	Foaming Capacity (%)	Foaming Stability (%)
27.50	3.50	$0.81{\pm}0.00^{f}$	$174.64{\pm}0.48^{f}$	$90.08{\pm}0.18^{de}$	$27.96{\pm}0.44^{f}$	$15.15{\pm}0.21^{f}$	$6.25{\pm}0.00^{e}$
30.00	3.50	$0.80{\pm}0.00^{e}$	$172.17{\pm}0.30^{g}$	$91.33{\pm}0.08^{f}$	$27.25{\pm}1.57^{f}$	$14.50{\pm}0.71^{f}$	$6.25{\pm}0.00^{e}$
27.50	2.00	$0.70{\pm}0.01^{b}$	$159.96{\pm}0.42^{f}$	$88.99{\pm}0.88^{cd}$	$24.80{\pm}0.79^{e}$	$11.57{\pm}0.11^{e}$	$5.08{\pm}0.03^{d}$
25.00	3.50	$0.70{\pm}0.00^{b}$	$127.45{\pm}0.57^{b}$	$78.80{\pm}0.33^{a}$	$21.47{\pm}0.50^{d}$	$8.00{\pm}0.00^{d}$	$3.78{\pm}0.04^{c}$
25.00	5.00	$0.65{\pm}0.01^{a}$	$172.29{\pm}0.05^{g}$	$106.13{\pm}0.49^{h}$	$20.69{\pm}0.79^{d}$	$7.43{\pm}0.25^{cd}$	$3.79{\pm}0.01^{c}$
27.50	5.00	$0.70{\pm}0.00^{b}$	$123.64{\pm}1.34^{a}$	$95.24{\pm}0.13^{g}$	$14.82{\pm}1.02^{b}$	$7.07{\pm}0.08^{bc}$	$3.55{\pm}0.35^{c}$
30.00	2.00	$0.73{\pm}0.00^{c}$	$151.13{\pm}0.30^{d}$	$91.23{\pm}0.53^{ef}$	$14.48{\pm}1.44^{b}$	$6.39{\pm}0.41^{b}$	$2.72{\pm}0.11^{b}$
25.00	2.00	$0.76{\pm}0.01^{d}$	$129.48{\pm}0.06^{c}$	$83.09{\pm}0.26^{b}$	$11.60{\pm}0.38^{a}$	$6.40{\pm}0.14^{b}$	$2.38{\pm}0.17^{b}$
30.00	5.00	$0.64{\pm}0.00^{a}$	$154.34{\pm}0.27^{e}$	$88.40{\pm}0.67^{c}$	$17.54{\pm}1.03^{c}$	$5.57{\pm}0.25^{a}$	$0.84{\pm}0.31^{a}$
27.50	3.50	$0.80{\pm}0.00^{e}$	$172.94{\pm}0.90^{g}$	$90.48{\pm}0.74^{ef}$	$27.21{\pm}1.53^{f}$	$14.80{\pm}0.12^{f}$	$6.17{\pm}0.03^{e}$

Means that do not share the same superscript in the same column are significantly different ($p>0.05$).

Table 2: Effect of steaming process as pre-treatment on functional properties of pigeon pea

Steaming temp (°C)	Steaming time (mins)	PBD (g/ml)	WAC (%)	OAC (%)	Swelling capacity (%)	Foam capacity (%)	Foam stability (%)
95.00	20	$0.66{\pm}0.00^{e}$	$149.85{\pm}1.05^{ef}$	$71.22{\pm}0.97^{e}$	$36.09{\pm}0.80^{d}$	$17.40{\pm}0.17^{a}$	$1.14{\pm}0.04^{a}$
97.50	20	$0.66{\pm}0.00^{e}$	$146.28{\pm}1.25^{d}$	$63.20{\pm}0.02^{d}$	$30.91{\pm}0.38^{cd}$	$32.40{\pm}0.65^{g}$	$2.83{\pm}0.05^{d}$
95.00	10	$0.64{\pm}0.00^{c}$	$127.13{\pm}0.71^{a}$	$62.59{\pm}0.37^{d}$	$29.20{\pm}0.09^{cd}$	$25.77{\pm}0.13^{d}$	$2.08{\pm}0.03^{c}$
97.50	30	$0.62{\pm}0.00^{b}$	$154.51{\pm}0.09^{g}$	$56.98{\pm}0.87^{c}$	$29.05{\pm}0.73^{cd}$	$20.97{\pm}0.65^{b}$	$2.88{\pm}0.03^{d}$
100.00	30	$0.63{\pm}0.00^{b}$	$154.45{\pm}1.95^{g}$	$75.08{\pm}6.90^{e}$	$27.45{\pm}0.02^{bcd}$	$24.27{\pm}0.03^{c}$	$4.28{\pm}0.02^{e}$
100.00	10	$0.67{\pm}0.00^{f}$	$132.81{\pm}2.00^{b}$	$51.02{\pm}0.13^{b}$	$22.18{\pm}1.68^{bc}$	$30.16{\pm}0.39^{f}$	$4.35{\pm}0.00^{f}$
97.50	10	$0.67{\pm}0.00^{f}$	$150.45{\pm}0.07^{f}$	56.20±0.28c	$15.99{\pm}0.24^{ab}$	$28.48{\pm}0.13^{e}$	$1.41{\pm}0.03^{b}$
95.00	30	$0.59{\pm}0.00^{a}$	$151.31{\pm}0.04^{f}$	$42.05{\pm}0.13^{a}$	$10.19{\pm}0.16^{a}$	$25.64{\pm}0.09^{d}$	$4.31{\pm}0.03^{ef}$
100.00	20	$0.64{\pm}0.00^{c}$	$147.46{\pm}1.40^{de}$	$39.22{\pm}0.47^{a}$	$21.55{\pm}14.57^{bc}$	$24.30{\pm}0.01^{c}$	$4.29{\pm}0.00^{ef}$
97.50	20	$0.65{\pm}0.00^{d}$	$139.50{\pm}1.41^{c}$	$65.31{\pm}0.06^{d}$	$30.06{\pm}0.76^{cd}$	$21.09{\pm}0.49^{b}$	$1.41{\pm}0.04^{b}$

Values are means ± standard deviation (SD). Different letters in the same column represent significant differences ($p< 0.05$ PBD=Packed Bulk Density, WAC= Water Absorption Capacity, OAC= Oil Absorption Capacity

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Table 3: Effect of roasting temperature and roasting time on functional properties

Roasting temp (°C)	Roasting time (mins)	BD (g/ml)	WAC (%)	OAC (%)	Swelling capacity (%)	Foam capacity (%)	Foam stability (%)
140	8.5	0.82±0.00[f]	142.30±0.70[cd]	78.38±0.10[d]	60.19±0.63[e]	14.31±0.02[b]	2.86±0.01[c]
160	8.5	0.83±0.00[g]	148.66±1.75[e]	76.67±0.17[bc]	54.94±0.62[d]	14.27±0.03[b]	1.41±0.03[b]
140	7	0.74±0.00[b]	144.31±0.47[d]	82.08±0.10[e]	49.01±0.39[c]	18.64±0.09[d]	2.90±0.03[c]
160	7	0.79±0.00[d]	138.57±0.00[b]	74.93±0.28[a]	44.86±0.29[b]	14.29±0.01[b]	1.42±0.02[b]
140	10	0.90±0.00[i]	156.61±0.09[f]	81.39±0.04[e]	35.38±0.96[a]	14.13±0.22[b]	1.44±0.01[b]
160	10	0.84±0.00[h]	142.04±0.65[c]	76.06±0.22[b]	44.97±0.52[b]	12.91±0.06[a]	1.43±0.00[b]
180	7	0.73±0.00[a]	135.79±0.42[a]	83.12±0.52[f]	43.75±5.15[b]	14.28±0.00[b]	2.81±0.07[c]
180	8.5	0.81±0.00[e]	142.52±0.48[cd]	83.95±0.18[f]	43.55±0.27[b]	16.12±0.27[c]	0.80±0.12[a]
180	10	0.77±0.00[c]	142.01±0.06[c]	76.06±0.13[b]	43.73±0.65[b]	14.30±0.04[b]	1.46±0.04[b]
160	8.5	0.83±0.00[g]	148.44±2.04[e]	77.65±1.23[cd]	44.24±0.20[b]	14.24±0.06[b]	1.42±0.02[b]

Values are means ± standard deviation (SD). Different letters in the same column represent significant differences (p< 0.05 PBD=Packed Bulk Density, WAC= Water Absorption Capacity, OAC= Oil Absorption Capacity

Effect of roasting as pre-treatment on functional properties of pigeon pea

Table 3 shows the packed bulk density, water absorption capacity, oil absorption capacity, swelling capacity, foaming capacity and foaming stability of the roasted samples at various temperatures and time. They were observed to be in the range 0.73-0.90 g/ml, 135.79-156.61%, 74.93-83.95%, 35.38-60.19%, 12.91-18.64%, 0.80-2.90%, respectively. The highest swelling capacity (60.19%) was observed in the sample roasted at 140 °C for 85 minutes, while the samples with the highest oil absorption capacity (83.95%) were samples roasted at 180 °C for 8.5 minutes. Agume *et al*. (2017) reported that roasting induces a decrease in the bulk density of soybean flour. Reduction in bulk density might be due to starch modification, reduction in denser compounds to simpler ones (breaking of starch) during processing and dispersibility of the processed flour (Ogori and Alimi, 2013). The reduced bulk density of flour can be essential to prepare infant and complementary foods. The water absorption capacity was observed to decrease with an increase in roasting temperature, whereas it increased with an increase in the roasting time. An increase in water absorption capacity can be a result of the formation of capillaries and porous structures in the endosperm, along with the destruction of starch as induced by gelatinization (Wani *et al*., 2015a).

This result is similar to the report of Sharma *et al*. (2020) on roasting of barley, chickpea, and linseed flours, respectively. High water absorption capacity has importance in the stabilization of starch against syneresis and the development of ready-to-eat foods due to increased cohesiveness. Reducing carbohydrate and protein interaction may expose more hydrophilic constituents, especially protein (Echendu *et al.*, 2004). The observed variation in water absorption capacity among the flours may be due to the degree of interaction of the protein with water and the conformational characteristics of the protein (Butt and Batool, 2010). It can be assumed that the polar amino acid residues of proteins with a strong attraction for water molecules could have increased the water absorption capacity of germinated horse gram flour (Sreerama *et al*., 2012).

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Effect of fermentation as pre-treatment on the pasting properties of the pigeon pea

Table 4 shows the values for the peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature of fermented pigeon pea flour at varying temperature and periods. The values of these responses were observed to range from 224.00 – 1814.00 RVU, 221.00 – 1225.00 RVU, 3.00 – 782.00 RVU, 1402.00 – 1769.00 RVU, 357.00 – 1001.00 RVU, 4.40 – 7.00 min and 50.25 – 92.10 ^{o}C respectively. The highest peak viscosity (1814.00 RVU), trough viscosity (1225.00 RVU), final viscosity (1769.00 RVU), setback viscosity (1001.00 RVU), peak time (7.00 min) and pasting temperature (92.10 ^{o}C) were observed in pigeon pea flours fermented at 60 ^{o}C for 3.5 days, 5 days, 2 days, 3.5 days and 3.5 days.

Peak viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature were observed to decrease initially and later increase as the fermentation temperature increased; however, they increased as the fermentation time increased. Contrarily, the trough viscosity was observed to increase in temperature but decreased with increased fermentation time. Peak viscosity is the ability of the starch to swell freely before its breakdown, and it is an indicator of the strength of the paste formed during processing (Ige, 2017). The decrease in the peak viscosity of pigeon pea flour is in consonance with the findings of Arukwe (2021) for the peak viscosity of wheat sprouted/fermented pigeon pea flour but contradictory to the claim of Ohizua *et al.* (2016) for peak viscosity of banana-pigeon pea-sweet potato flour. The increase in peak viscosity of the pigeon pea flour could be attributed to starch damage which further correlated with the final product quality (Arukwe *et al.*, 2021).

The breakdown viscosity is due to the disintegration of gelatinised starch granules structure during continued stirring and heating, thus, indicating the shear thinning property of the pigeon pea flour (Yadav *et al.*, 2011). The reduced breakdown viscosity of the pigeon pea flour relative to the fermentation time will be beneficial as the pigeon pea flour will have stability under production processes, especially when used as a composite (Arukwe, 2021). Similar findings have been reported by Yadav *et al.* (2011) for the breakdown viscosity of lafun-pigeon pea flour but contradictory to the work of Bolaji *et al.* (2021) for the breakdown viscosity of rice-pigeon pea flour noodles.

Final viscosity is the parameter used to determine the quality of a starch-based sample. It gives an idea of the ability of starch to gel after cooking and cooling and indicates the stability of cooked paste in actual use (Shimelis *et al.*, 2006).This justifies the increase in the final viscosity of the pigeon pea flours, which indicates that the flours may not be stable during cooling, but these are contradictory to the reports of Chinomso *et al.* (2017) for final viscosity of sprouted-boiled-fermented pigeon pea flours and five Nigerian varieties of pigeon pea flour by Adenekan *et al.* (2014).

The setback viscosity correlates with the texture of various flour samples. Increased setback values of the pigeon pea flours relative to fermentation time showed that they might have less resistance to retrogradation (Adebowale *et al.*, 2005). This could be attributed to higher amylose content as the linear structure of amylose favours more intermolecular hydrogen bonding than amylopectin, which has a branched structure (Yadav *et al.*, 2011).Similar observations have been reported by Bolaji *et al.* (2021) for the setback viscosity of *lafun*-pigeon pea flour and Arukwe *et al.* (2017) and setback viscosity of wheat flour supplemented with combined processed pigeon pea flour. Peak time is a measure of cooking time (Adebowale *et*

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al., 2005). The decrease in the peak time of the pigeon pea flours infers that they will have less cooking time and low energy consumption potential.

The pasting temperature usually is a measure of the lowest temperature needed to cook any food sample, composite flours with higher pasting temperatures may not be recommended for certain products due to the high cost of energy (Olumurewa *et al*., 2019). The pasting temperature of the pigeon pea flours suggests that they could have high water absorption capacity (Julanti *et al*., 2015). Ohizua *et al.* (2016) reported synonymous findings for the pasting temperature of pigeon pea-sweet potato flour.

Trough viscosity is the maximum viscosity at the constant temperature phase of the rapid visco analyser profile and the ability of the phase to withstand breakdown during cooling (Akoja and Coker, 2018). The increase in trough viscosity of the pigeon pea flours was due to the fermentation process, which further resulted in less paste stability of the flours. The report agrees with the work of Fasoyiro and Arowora (2013) for sprouted-fermented pigeon pea flour.

Effect of steaming as pre-treatment on the pasting properties of pigeon pea flour

Table 5 depicts the values for the peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature of steamed pigeon pea flour at different temperature and periods. The values of these responses were observed to range from 1289.75 – 1917 RVU, 920.75 – 1224.75 RVU, 64.75 – 806.75 RVU, 1641.75 – 1878.75 RVU, 416.75 – 989.75 RVU, 4.02 – 6.75 min, 79.65 – 89.35 ^{o}C. The peak viscosity, trough viscosity, final viscosity and peak time were noted to decrease initially but later sharply increased as the steaming temperature increased; however, they increased sharply with increased steaming time. Contrarily, breakdown viscosity and setback viscosity were observed to increase with time but decreased with an increase in temperature. An increase in peak viscosities of the pigeon pea flours pointed to the presence and interaction of components including fats, protein and starch. Additionally, their higher peak viscosities will yield high viscous paste or gel during cooking and cooling and could also be potential dietary bulk (high volume/high viscosity) (Otegbayo *et al.*, 2006).

Trough viscosity dictates the ability of the paste or gel formed to withstand breakdown during cooling (Ayo-Omogie and Ogunsakin, 2013). It is also the maximum viscosity at the constant temperature phase of the rapid visco analyser profile and the ability of the phase to withstand breakdown during cooling (Akoja and Coker, 2018). The increase in trough viscosity of the pigeon pea flours relative to sharp increase with increased steaming time is indicative of the flours' ability to withstand breakdown during cooling and thus could find good application in food systems where paste stability during cooling is required (Raji *et al.*, 2020). This report is not in agreement with the findings of Adenekan *et al.* (2014) for the trough viscosity of five selected varieties of Nigerian pigeon pea and the study of Ohizua *et al.* (2016) for the trough viscosity of banana-pigeon pea-sweet potato flour blends.

Breakdown gives an indication of the susceptibility of cooked starch granules to disintegrate during continued stirring and heating, which illustrates the stability or consistency of the paste during cooking (Ohizua *et al.*, 2016; Zhang *et al.*, 2019). This explains the breakdown viscosity of the pigeon pea flours, which increased due to the leaching of amylose, thus showing the low capability of the flours to withstand heating and shear stress. The report is dissimilar to the study of Ohizua *et al.*, 2016) for the breakdown viscosity of unripe-banana-pigeon pea-sweet

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potato flour and the report of Agume*et al.* (2017) for the breakdown viscosity of roasted and soaked soy flour.

The final viscosity, indicating the ability of food material to form a viscous paste, has been reported in previous works of Adebowale *et al*. (2005) and Maziya-Dixon *et al*. (2007) as the most commonly used parameters to determine the ability of the starch-based material to form a viscous paste or gel after cooking and cooling, as well as the resistance of the paste to shear force during stirring. The final viscosity of the pigeon pea flour increased with an increase in steaming temperature, hence, indicating that the flour will form gel more quickly after being cooked into the dough. Bento *et al.* (2022) reported similar findings for raw and cooked carioca beans.

The setback viscosity of the pigeon pea flours, which increased with an increase in steaming temperature, represents the tendency of the flours to retrograde due to the starch molecules in the steamed pigeon pea flours having high mobility, which did not retain water into the gel matrix (Li *et al*., 2016). Also, the pigeon pea flours are bound to have reduced dough digestibility due to their high setback viscosity (Akinjayeju *et al.*, 2020). Considerably, pastes could be produced from flours and stored with minimum retrogradation (Oti and Akobundun, 2007). The findings of Chinomnso (2021) regarding the setback viscosity of pigeon pea-wheat flour agree with this study.

A decrease in the peak time of the pigeon pea flours with an increase in steaming temperature showed that the flours would have less cooking time (<6 min), thus finding applicability in the production of foods where shorter processing time is required (Raji *et al.*, 2020) and further agrees to the claim of Fasoyiro and Arowora (2013) for the peak time of *ogi* fortified with pigeon pea and the work of Ohizua *et al.* (2016) for the peak time of unripe cooking banana-pigeon pea and sweet potato flour.

The pasting temperature of the pigeon pea flours, which increased with increased steaming temperature, was due to the presence of non-starch components (i.e., proteins, oligosaccharides, cellulose, etc.), which made the flours have high resistance to swelling. These components/compounds competed with the starch for water, which reduced the water availability increasing the pasting temperature. Besides, the resistant starch in the steamed pigeon pea contributed to a higher resistance to swelling and rupturing (Romero and Zhang, 2019). Literature has also pointed out that flours of pulses, such as pigeon peas, could contain a high amount of amylose (around 30%) compared to cereal (around 10%); hence, the high content of amylose might result in a high gelatinisation temperature due to the orientation of amylose chains relative to one another, or strong interactions between starch chains, which increased the stability of the granules to rupture under mechanical agitation (Li *et al*. 2016). This report corroborates the work of Felker *et al.* (2018) for pasting the temperature of raw navy, black, and pinto bean flours.

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Table 4: Effect of fermentation temperature and time on pasting properties of fermented pigeon pea flours

Fermentation Temp. (ºC)	Fermentation time (days)	Peak viscosity	Trough	Breakdown Viscosity	Final viscosity	Setback	Peak time	Pasting Temp.
27.50	3.50	577.00±0.02^{d}	501.00±0.11^{c}	76.00±0.02^{d}	1436.00±1.10^{bc}	935.00±0.03^{ab}	5.07±0.01^{e}	86.35±0.05^{a}
30.00	3.50	1290.0±0.05^{bc}	1225.0±0.12^{b}	65.00±0.01^{ab}	1642.00±0.04^{b}	417.00±0.02^{ab}	7.00±0.02^{d}	83.95±0.03^{c}
27.50	2.00	1814.00±0.01^{b}	1032.0±0.10^{d}	782.00±0.02^{a}	1769.00±0.01^{a}	737.00±0.12^{bc}	5.20±0.01^{e}	50.25±0.01^{b}
25.00	3.50	1215.00±0.03^{a}	729.00±1.10^{e}	486.00±0.05^{c}	1688.00±0.05^{c}	959.00±2.52^{bc}	5.87±0.03^{e}	90.65±0.04^{a}
25.00	5.00	224.00±0.03^{ab}	221.00±0.02^{bc}	3.00±1.12^{f}	1578.00±0.01^{b}	357.00±0.05^{bc}	6.67±0.05^{d}	92.10±0.01^{a}
27.50	5.00	624.00±0.01^{ab}	548.00±0.05^{ab}	76.00±0.03^{d}	1549.00±0.04^{c}	1001.0±1.16^{d}	5.13±0.03^{e}	85.60±0.05^{b}
30.00	2.00	1421.00±0.01^{d}	983.00±1.11^{c}	438.00±1.53^{c}	1517.00±0.05^{a}	534.00±0.07^{a}	4.80±0.01^{a}	76.65±0.01^{d}
25.00	2.00	1299.00±0.03^{a}	714.00±1.73^{c}	585.00±0.03^{bc}	1402.00±0.04^{b}	688.00±0.01^{bc}	5.60±0.03^{e}	77.55±0.03^{c}
30.00	5.00	1368.00±0.01^{c}	992.00±0.51^{ab}	376.00±0.03^{a}	1434.00±1.80^{ab}	442.00±1.53^{a}	4.40±0.02^{a}	80.75±0.01^{b}
27.50	3.50	1215.0±1.10^{bc}	729.00±1.53^{e}	486.00±0.02^{bc}	1688.00±0.47^{c}	959.00±0.03^{ab}	5.87±0.01^{e}	90.65±0.05^{a}
P Level		**	**	**	**	**	**	**

Values are mean ± standard deviation. Data with different superscripts in the same column are significantly different at p <0.05

Table 5: Effect of steaming temperature and time on pasting properties of steamed pigeon pea flours

Temp. (ºC)	Steaming time (days)	Peak viscosity	Trough	Breakdown Viscosity	F. viscosity	Setback	Peak time	Pasting Temp.
95	20	1524.75± 0.35^{f}	1142.75±0.35^{h}	381.75±0.35^{b}	1878.75±0.35^{k}	735.75±0.35^{d}	4.95± 0.35^{b}	81.25± 0.35^{bc}
97.5	20	1627.75± 3.18^{h}	927.75±3.18^{g}	699.75±0.35^{h}	1857.75±0.35^{i}	927.75±0.35^{f}	5.62± 0.35^{b}	82.00± 0.35^{c}
95	10	1727.75± 0.35	920.75±0.35^{f}	806.75±0.35^{k}	1740.75±0.35^{d}	819.75±0.35^{e}	5.55± 0.35^{b}	80.65± 0.35^{b}
97.5	30	1375.75± 0.35^{b}	810.75±0.35^{c}	564.75±0.35^{d}	1789.75±0.35^{f}	978.75±0.35^{h}	5.55± 0.35^{b}	89.35± 0.35^{f}
100	30	1680.75± 0.35^{i}	1160.75±0.35^{i}	519.75±0.35^{c}	1688.75±0.35^{b}	527.75±0.35^{b}	4.02± 0.35^{a}	79.75± 0.35^{a}
100	10	1480.75± 0.35^{d}	823.75±0.35^{d}	656.80±0.28^{f}	1813.75±0.35^{g}	989.75±0.35^{j}	5.48± 0.35^{b}	87.00± 0.35^{e}
97.5	10	1917.75± 0.35	1159.75±0.35^{i}	756.75±0.35^{j}	1833.75±0.35^{h}	968.75±0.35^{c}	5.02± 0.35^{b}	79.65± 0.35^{a}
95	30	1539.75± 0.35^{g}	885.75±0.35^{e}	653.80±0.28^{e}	1875.75±0.35^{j}	989.75±0.35^{j}	5.62± 0.35^{b}	84.45± 0.35^{d}
100	20	1514.75± 0.35^{e}	791.75±0.35^{b}	722.75±0.35^{j}	1760.75±0.35^{e}	968.75±0.35^{g}	5.35± 0.35^{b}	87.75± 0.35^{e}
97.5	20	1406.75± 0.35^{c}	729.75±0.35^{a}	676.75±0.35^{g}	1711.75±0.35^{c}	981.75±0.35^{i}	5.22± 0.35^{b}	89.35± 0.35^{f}
P Level		P < .05	P < .05	P < .05	P < .05	**	**	**

Values are mean ± standard deviation. Data with different superscripts in the same column are significantly different at p < .05.

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Effect of roasting as pre-treatment on the pasting properties of pigeon pea flour

Table 6 depicts the values for the peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature of roasted pigeon pea flours at various temperature and periods. The values of these responses were observed to range as 594.00 – 1290.00 RVU, 456.00 – 1225.00 RVU, 65.00 – 604.00 RVU, 973.00 – 1642.00 RVU, 346.00 – 721.00 RVU, 4.33 – 7.00 min and 55.00 – 96.80 °C respectively. The highest peak viscosity (1290.00 RVU), trough viscosity (1225.00 RVU), breakdown viscosity (604.00 RVU), final viscosity (1642.00 RVU), setback viscosity (721.00 RVU), peak time (7.00 min) and pasting temperature (96.80 °C) were observed in pigeon pea flours roasted at 160 °C for 4.5 min and 6 min respectively. The trough viscosity, breakdown viscosity, final viscosity, setback viscosity and peak time were observed to decrease initially but later increased with an increase in roasting temperature increased. However, peak viscosity and pasting temperature were noted to increase with time but decreased with an increase in the temperature of roasting. Trough viscosity, which depicts the minimum viscosity value in the constant temperature phase of the RVA profile, measures the ability of paste to withstand breakdown during cooling (Okorie *et al.*, 2016). The decrease observed in trough viscosity of the roasted pigeon pea flours with increased roasting temperature was due to the leaching of amylose, amylose–lipid complex formation and granule swelling. The report is contradictory to the claim of Acevedo *et al.* (2017) for pigeon pea flours subjected to germination, soaking-cooking and microwaving but will find good application in food systems where high paste stability during cooling is required (Adegunwa *et al.*,2015).

The parameter mostly used to determine the quality of starchy food is the final viscosity which indicates the material's ability to form a gel after cooking (Sanni *et al.*, 2006; Awoyale *et al.*, 2022). The pigeon pea flour will form gels more quickly when being cooked, as shown in the 3D surface diagram for final viscosity (figure 4.3). Ige (2017) and Acevedo *et al.* (2017) reported dissimilar findings for plantain-pigeon pea-maize flours and pigeon pea flour subjected to germination, soaking-cooking and microwaving. The point where retrogradation of starch molecules occurs is known as the setback viscosity. Lower setback viscosity during the cooling of paste indicates a better resistance to retrogradation (Adebowale *et al.*, 2007; Awoyale *et al.*, 2022). This explains the setback viscosity of the pigeon pea flours, which made them prone to smaller tendencies to retrograde, thus being advantageous in food products such as soups and sauces that undergo loss of viscosity and precipitation as a result of retrogradation (Adebowale and Lawal, 2003).

The peak time gives an indication of the ease of cooking; therefore, the shorter the peak time, the better the ease of cooking (Adegunwa *et al*., 2015). The pigeon pea flours will undergo cooking with ease (≤ 7 min), and this is similar to the observation of Fasoyiro and Arowora (2013) for pigeon pea fortified *ogi*. Peak viscosity dictates the maximum viscosity developed during or soon after the heating aspect of a flour test (Adebowale *et al*., 2008). High peak viscosities of the pigeon pea flours in this study could be attributed to weaker cohesive forces within the granules, thus leading to further disintegration when used in food formulations without a shearing effect (Raji *et al.*, 2020). This is related to the proportion of native starch (50%) present in pigeon peas (Acevedo *et al.*, 2013). Additionally, the amylose–amylopectin ratio and the flour protein content could also be involved (Kaushal *et al*., 2012).

The first detectable viscosity measured in an amylogram is the pasting temperature, which is a reflection of the swelling of the starch paste and is affected by the starch concentration level (Mufumbo *et al*., 2011). The pigeon pea flour will form paste below the boiling point of water

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(100 ^{o}C), and this is beneficial as it guarantees their suitability in food and non-food industrial processes because of the reduced energy costs incurred (Awoyale *et al.*, 2017). Also, the exploitation of a wide range of options in terms of their utilisation in the industrial sector is possible (Mufumbo *et al.*, 2011). Adenekan *et al.* (2014) reported similar findings for five varieties of Nigerian pigeon pea flou

Table 6: Effect of roasting temperature and time on pasting properties of roasted pigeon pea flours

Roasting Temp. (ºC)	Roasting time (min)	Peak viscosity	Trough	Breakdown Viscosity	Final viscosity	Setback	Peak time	Pasting Temp.
160	8.5	1018.00±0.02[d]	539.00±0.11[c]	479.00±0.02[d]	1145.00±1.10[bc]	606.00±0.03[ab]	5.53±0.01[b]	88.80±0.05[a]
180	8.5	997.00±0.05[ab]	738.00±0.12[bc]	259.00±0.01[ab]	1116.00±0.04[b]	378.00±0.02[ab]	5.13±0.02[d]	83.95±0.03[c]
160	7	1099.00±0.01[b]	846.00±0.10[d]	253.00±0.02[a]	1192.00±0.01[a]	346.00±0.12[bc]	4.33±0.01[d]	80.80±0.01[b]
140	7	1252.00±0.03[a]	700.00±1.10[e]	552.00±0.05[c]	1127.00±0.05[c]	427.00±2.52[bc]	4.87±0.03[c]	78.35±0.04[a]
160	10	1127.00±0.03[ab]	594.00±0.02[bc]	533.00±1.12[bc]	1315.00±0.01[b]	721.00±0.05[bc]	5.67±0.05[d]	88.75±0.01[a]
180	10	1278.00±0.01[ab]	674.00±0.05[ab]	604.00±0.03[a]	1106.00±0.04[c]	432.00±1.16[d]	5.00±0.03[d]	56.45±0.05[b]
160	7	843.00±0.01[d]	474.00±1.11[c]	369.00±1.53[a]	1191.00±0.05[a]	717.00±0.07[a]	5.60±0.01[c]	91.85±0.01[d]
180	8.5	594.00±0.03[a]	456.00±1.73[c]	138.00±0.03[ab]	973.00±0.04[b]	517.00±0.01[bc]	7.00±0.03[a]	55.00±0.03[c]
140	10	1206.00±0.01[c]	654.00±0.51[ab]	552.00±0.03[a]	1367.00±1.80[ab]	713.00±1.53[a]	5.73±0.02[a]	89.55±0.01[b]
160	8.5	1290.00±1.10[bc]	1225.00±1.53[a]	65.00±0.02[a]	1642.00±0.47[c]	417.00±0.03[ab]	7.00±0.01[a]	96.80±0.05[a]
P Level		**	**	**	**	**	**	

Values are mean ± standard deviation. Data with different superscripts in the same column are significantly different at p < .05.

CONCLUSION

This study examined the effects of pre-treatment conditions (fermentation, steaming and roasting) on the functional and pasting properties of pigeon peas. The effects on other parameters are a work in progress. It can be concluded that there are correlations between the treatments versus the functional and pasting properties of pigeon peas. The optimum conditions for the variables investigated with fermented, steamed, and roasted pigeon peas with suitable quality characteristics were fermentation temperature of 27 ^{o}C for 4 days, steaming at 100 ^{o}C for 20 minutes, and roasting at 140 ^{o}C for 8 minutes. The pasting properties are also reflective of the functional properties so also the response surface plots. The desirability function technique examined the optimum conditions that maximise the processing conditions of pigeon pea quality attributes. This information will be necessary for utilising pigeon peas with improved physical conditions for exploitation on a large scale.

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RECOMMENDATION

From the study, it can be recommended that: Pigeon peas are to be fermented at a temperature of 27 ^{o}C for 4 days, steamed at 100 ^{o}C for 20 minutes, roasting at 140 ^{o}C for 8 minutes for production of allied foods products.

Production of pigeon pea flour on a large scale and composite with other cereal flour can be used as a composite for other product work as its product development. Further work can be done on the effects of these treatments on the shelf life and the anti-nutritional factors of the beans.

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